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In-Situ F2-Region Plasma Density and Temperature Measurements from the International Space Station

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Introduction

The International Space Station orbit provides an ideal platform for in-situ studies of space weather effects on the mid and low-latitude F-2 region ionosphere. The Floating Potential Measurement Unit (FPMU) operating on the ISS since Aug 2006, is a suite of plasma instruments: a Floating Potential Probe (FPP), a Plasma Impedance Probe (PIP), a Wide-sweep Langmuir Probe (WLP), and a Narrow-sweep Langmuir Probe (NLP). This instrument package provides a new opportunity for collaborative multi-instrument studies of the F-region ionosphere during both quiet and disturbed periods. This presentation first describes the operational parameters for each of the FPMU probes and shows examples of an intra-instrument validation. We then show comparisons with the plasma density and temperature measurements derived from the TIMED GUVI ultraviolet imager, the Millstone Hill ground based incoherent scatter radar, and DIAS digisondes. Finally we show one of several observations of night-time equatorial density holes demonstrating the capabilities of the probes for monitoring mid and low latitude plasma processes.

Figure 1. FPMU deployed on the ISS starboard S1 truss.

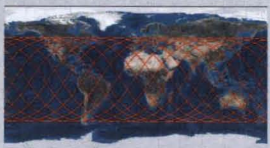


Figure 2. Typical ISS ground track.

Configuration, Measurement Parameters

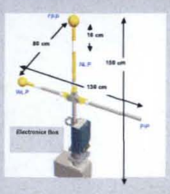


Figure 3. FPMU layout (Swenson et al., 2003)

Sensor	Measured Parameter	Rate (Hz)	Effective Range
FPP	V_F	128	-180 to +180 V
WLP	N T_e V_F	1	10^9 to $5\cdot10^{12}$ m^{-3} 500 to 3000 K -20 to 80 V
NLP	N T_e V_F	1	10^9 to $5\cdot10^{12}$ m^{-3} 500 to 3000 K -180 to +180 V
PIP	N	512	$1.1\cdot10^{10}$ to $4\cdot10^{12}$ m^{-3}

Table 1. Measured parameters, rates, and effective ranges for the FPMU.

The FPMU operation is autonomous with either an on or off state. The only control is over the operation of a heater in the WLP. The FPMU is mounted to a camera port and its data is transmitted via the Ku-band. The camera interface allows for high bandwidth – 6,776 12-bit words each second. For 2007 the AOS for the Ku-band is ~60%-65%.

Probe Description

FPP – a gold-plated sphere of radius 5.08 cm isolated from chassis ground by approximately 10^{11} Ω.

PIP - a short dipole antenna electrically isolated from the ISS that measures the electrical impedance at 256 steps from 100 KHz to 20 MHz. in one second and tracks the UHF resonance at 512 Hz.

WLP - a gold-plated sphere of radius 5.08 cm that performs a 2,048-point voltage sweep from –20 V to 80 V relative to chassis ground. Two different voltage step sizes (25 mV and 250 mV) are used. An internal heater allows surface cleaning.

NLP - a gold-plated cylinder with radius 1.43 cm and length 5.08 cm that performs a 512-point voltage sweep from -4.85 V to +4.85 V about a reference potential determined by the FPP. A constant voltage step size of 12 mV is used.

For each Langmuir probe, the voltage varies from low to high over one second and from high to low the next second with the collected current measured in two gain channels.

Sample Data

Figures 4 summarizes FPMU data for orbit day 2007/062. The top panel contains floating potential measurements from the FPP, WLP, and NLP. The ISS charges negative with respect to the plasma (graphed as a positive number here). The middle panel shows the density derived from the PIP, WLP, and NLP. The bottom panel shows the electron temperature derived from the WLP and NLP. (Wright et al., 2008)

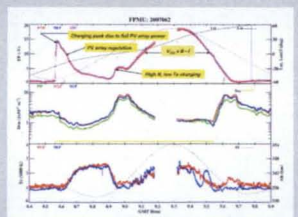


Figure 4. Sample data from each of the FPMU four probes from 2007/062.

FPMU Operation Record

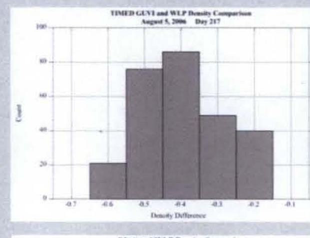
Year	Approx. GMT Duration	Calendar Days
2006	215/22:30 – 220/14:30	Aug 3 - 8
2007	022/19:15 – 031/00:00	Jan 22 – 30
	060/12:00 – 063/00:00	Mar 1 – 3
	103/12:00 – 104/12:00	Apr 13 -14
	123/00:23 – 124/00:00	May 3
	165/10:23 – 169/04:00	Jun 14 – 18
	187/03:47 – 191/00:00	Jul 6 - 9
	253/13:00 – 257/03:00	Sep 10 – 14
	301/18:10 – 307/02:00	Oct 28 – Nov 3
	312/05:52 – 312/10:33	Nov 8
	324/22:35 – 327/19:05	Nov 20 – 23
	354/14:56 – 355/23:53	Dec 20 – 21
2008	022/23:45 - 037/16:00	Jan 22 – Feb 6
	067/16:57 – 074/22:28	Mar 7 – 14
	086/00:00 – 088/23:57	Mar 26 – 28
	099/13:30 – 101/09:32	Apr 8 – 10
	126/23:42 – 131/01:05	May 5 - 10

Table 2. Operation dates of FPMU instrument suite.

Independent Data Verification

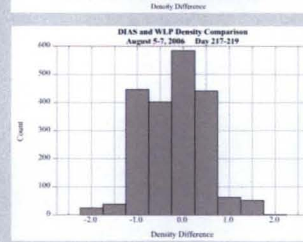
The density and temperatures derived from the WLP and NLP Langmuir probes were compared to measurements from the incoherent scatter radar (ISR) at Millstone Hill, the European Digital Upper Atmosphere Server (DIAS) digisondes, and the TIMED Global Ultraviolet Imager (GUVI). Differences between the WLP and these instruments are given below where the difference = difference/average of the two measurements. (Coffey et al., 2008).

Data Verification - Densities



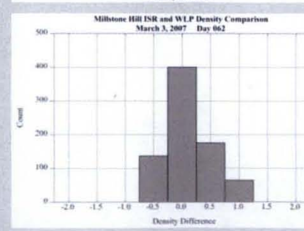
TIMED GUVI Ultraviolet Imager

Figure 5. Difference in densities between TIMED GUVI and WLP on 2006/217.



DIAS

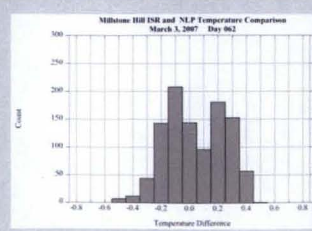
Figure 6. Difference in densities between DIAS digisondes and WLP on several days in 2006.



Millstone Hill Incoherent Scatter Radar

Figure 7. Difference in densities between Millstone Hill ISR and WLP on 2007/062.

Data Verification - Temperatures



Millstone Hill Incoherent Scatter Radar

Figure 8. Difference in temperatures derived between Millstone Hill ISR and NLP on 2007/062.

Observations of Nighttime Equatorial Holes

Since operation started in 2006, the FPMU plasma probes, WLP, NLP, and PIP have observed several nighttime equatorial holes extending to densities below 1×10^{10} m^{-3}. Figure 9 below shows continuous examples of deep density cavities during active geomagnetic conditions occurring on March 9, 2008. Panels in Figure 10 present the geomagnetic indices for this day.

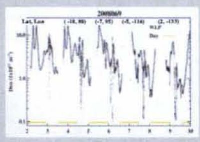


Figure 9. Several equatorial density holes observed sequentially by the WLP on March 9, 2008. Day 069 during active geomagnetic conditions.

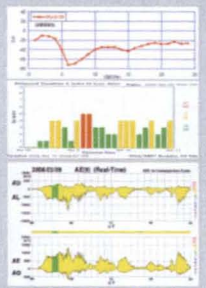


Figure 10. Dst, Kp, and auroral electrojet activity indices for March 9, 2008, Day 069.

Summary and Future Operations

Since August 2006, the FPMU has been operated during several data sessions and is meeting its primary requirement of providing floating potential measurements of the ISS and its secondary requirement of providing measurements of the local ionospheric plasma. It will continue to operate during intermittent data campaigns at least through 2008 and possibly through 2010. Potential science goals of interest to the I-T community that could be addressed by the FPMU include:

*Spread-F density perturbations, *Motion of light ion troughs and plasmapause boundary during geomagnetic storms. *Storm time variations of density and temperatures in equatorial anomaly regions. *Electron temperature and density associated with sub-auroral ion drift (SAID) regions. *Electron temperatures in stable auroral red (SAR) arcs. *Collaborative studies with ground based remote sensing (ISR, ionosonde) and space based in-situ (C/NOFS, CHAMP, COSMIC, GPS ionospheric tomography) sensors. *Validation of real-time ionospheric forecast models (GAIM, etc.) *Interaction of large vehicles with ionospheric plasma.

References, Acknowledgements

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